

Effects of Different Business Environments on Demand Forecast Based Modelling of Supply Chain

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Abstract

The aim of this paper is to study the effects of different business environments on supply chain modelling and to find strategies for identifying critical success factors in a specific business environment. The management of supply chain is based on demand forecasts. The paper concentrates on modelling and control of the supplier network in an e-logistics environment by using a system theoretical approach. Demand forecasts are used as input information for supply chain modelling and control. Case companies are from food industry, project business and IT-wholesales. This enables the comparison of different business environments and modelling methods and the analysis of suitability of different modelling methods for different business environments. As a goal of the research project, a modelling guidebook is to be provided to companies striving for modelling improvements.

Keywords

Modelling, supply chain, forecasting, demand

1 Introduction

In the academic world, supply chain modelling and control are not new areas. Though, when combined with forecasting and using forecasts as input information for modelling, the situation is different: there are few studies existing. These previous studies usually cover the theory of demand forecasting and emphasize their importance, but they do not implement the theory into real supply chain management of industrial companies.

The aim of this paper is to study the effects of different business environments on supply chain modelling. We also try to find strategies for defining critical success factors in different business environments. The management of supply chain is based on demand forecasts. The paper concentrates on modelling and control of the supplier network in an e-logistics environment by using a system theoretical approach. Demand forecasts are used as input information for supply chain modelling and control. Case companies are from food industry, project business and IT-wholesales. This enables the comparison of different business environments and modelling methods and the analysis of suitability of different modelling methods for different business environments. As a goal of the research project, a modelling guidebook is to be provided to companies striving for modelling improvements. The aim of the book is to help the companies to find appropriate modelling methods and tools to suit the characteristics of their business environment.

We start with existing theories and work and continue by having a look at the research approach. Next, we discuss the basic concepts of modelling and control of supply chain. Then, we

introduce some tools for managing logistics and study the strategies for defining critical success factors in different business environments. Finally, we describe business environments and critical success factors of the case companies.

2 Existing Theories and Work

Supply chain is usually modelled using event based modelling, e.g. Chang and Makatsoris (2001) study the requirements for supply chain discrete event simulation modelling. Though, there are studies using different approaches. Petrovic et al. (1999) study supply chain modelling using fuzzy sets. Chen and Tzeng (2000) have a fuzzy multi-objective approach to the supply chain model and Carlsson and Fullér (2000) present a fuzzy approach to the bullwhip effect. They consider a series of companies in a supply chain, each of which orders from its immediate upstream member. They show that if the members of the supply chain share information and agree on better fuzzy estimates (as time advances) on future sales for the upcoming period then the bullwhip effect can be significantly reduced.

Li and O'Brien (1999) use dynamic and objective programming for modelling supply chain efficiency. Minner (2001) aims at modelling complexity in a supply chain. Angerhofer and Angelides (2000) give an overview of recent research work on system dynamics modelling in supply chain management. They focus on inventory decision and policy development, time compression, demand amplification, supply chain design and integration and international supply chain management.

Schönsleben (1998) has studied demand forecasts and forecast methods in supply chain management. He divides forecast methods into history-based and future-based methods. History-based demand forecasts are analytic methods based on consume statistics. They can be further divided into mathematical and graphic methods. Future-based demand forecasts use already existing information about future demand e.g. offers, confirmed orders in a contracting phase and interviews on customer behaviour. [Schönsleben 1998]

3 Research Approach

Systems research in logistics and operations management has usually both a positivistic and a quantitative research approach [Holweg 2001]. In our research most of the studies have been qualitative ones because of the lack of specially defined theory and a small number of cases. Data collection has included interviews, structured qualitative questionnaires and observations. Data sources have involved three engineering companies. The number of cases is suitable enough for case-study approach; the recommendable range is from four to six. The project was started with a study about present situation and future logistics strategies of case companies. The study was a semistructured interview for strategic managers of the case companies. Interviewees were presented a list of open questions involving their current practices and aims for the future. Next, state-of -the-art study about related modelling methods, existing tools and practices for supply chain management was done. It was based mostly on literature but included also a couple of interviews. Modelling was done with Simulink and with an event-based modelling and simulation tool called Simo-3.

4 Modelling and Control of Supply Chain

The word 'model' derives from the Latin word modellu(m), which has roots in the word modulus, measure. The world can be seen as a combination of static and dynamic systems. The measure of static systems is known instinctively, while dynamics systems are more complex, and their understanding implies the possibility to predict their future behaviour. A model is an abstract and

partial representation of some aspect or aspects of the world “that can be manipulated to analyze the past, define the present, and to consider possibilities of the future” [Smyth 1998, p.191].

Today, modelling and simulation are recognised as a separate inter-disciplinary research area distinct from computer science, mathematics, AI, etc. with a vast range of applications. Modelling covers the understanding and representation of structure and behaviour at an abstract level, whereas simulation produces behaviour as a function of time based on abstract model and initial conditions.

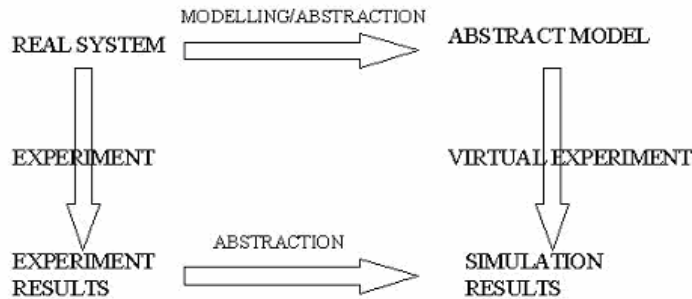


Figure 1: Lumped model between model and system

The *homomorphic* relation between model and system is a basis to the lumped model scheme: building a model of a real system and subsequently simulating its behavior should yield the same results as performing a real experiment followed by observation and codifying the experimental results (cf. Figure 1). A simulation model is a tool for achieving a certain goal e.g. design, analysis, control and optimization. [Birta, Ösmizrak 1996]

There are several ways to classify supply chain modelling. One is to divide supply chain models into continuous and discrete event models (cf. Figure 2). Systems dynamics models and transfer function models are examples of continuous models. Forrester started to study the use of business dynamics for management decision support in the late 1950's. This has led on to the development of systems dynamics [Sterman 2000]. Systems dynamics is a theory that studies the structure of feedback systems and influence of the structure on the behaviour of the systems. Also transfer function theory can be used for modelling that is continuous in time and state. [Towill 1982]

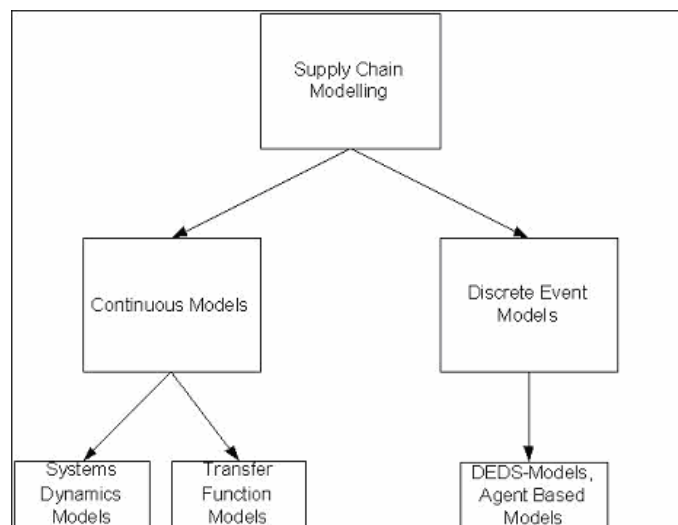


Figure 2: The most common methods for supply chain modelling

Discrete event based dynamic systems (DEDS) models and agent based models are the most common discrete event models. Systems built by humans (information networks, traffic systems and piece goods production) are usually of discrete nature. The state of these dynamic systems changes as a consequence of events. Natural systems are usually continuous in which case also the change of states is continuous. The need to describe man-made systems better has led to the development of discrete event-based dynamic systems (DEDS) theory. Due to the heterogeneity of discrete systems, DEDS is not just a single modelling method, but a collection of significantly different modelling methods. It can be considered as a union of artificial intelligence, operation research and systems theory [Ho 1989]. Furthermore, agent-based modelling has found favour with supply chain modellers lately [Swaminathan 1998]. Control, composed of tasks for individual agents, is included in an agent model. It can be impossible to see the target function of the whole model in large agent models.

When we are to develop ways to control a supply chain, we would like to test the system developed. But unlike with a traditional process in systems theory, we cannot do tests with a real chain. Accordingly, we need a model of the system to test it. With the model it is possible to take account of the specific characteristics of the system and to exploit them in control planning. The popularity of push-pull system in the development in supply chain control has increased lately. The production is usually forecast based until the assembly phase that is controlled in a demand based way [Ahn, Kaminsky, 2003]. The use of forecast methods is emphasized in a push phase of production. In order to define appropriate production and stock levels is it important to quantify the demand uncertainty and to utilize it in production control.

5 Tools for Managing Logistics

Manugistics, i2, iManage, Logility, SAP, Escalate Supplier 6.0 and Mapics are supply chain management tools in worldwide use. Beyond traditional supply chain management these tools devote to increase cooperation, transparency, and knowledge management. Many of them aim to support risk and product lifecycle management as well.

In dynamic business environment meaning of Customer Relationship Management (CRM) is emphasized. This means management of the whole business process. CRM could help companies e.g. at fast pricing, order handling, contract management and real time data processing. All above-mentioned functions play major role in supply chain management. J.D Edwards CRM 2.0, Frontstep CRM, SAIC Scoptima Solutions and Mapics are the most common CRM tools.

Supply Chain Council (SCC) has developed a cross-industry standard for supply chain management called Supply Chain Operations Reference-model (SCOR). Model integrates business processes reengineering, benchmarking and process measurement into a cross-functional framework. SCOR is based on five management processes, which are supply, make, deliver, plan and return. Model is hierarchical and consists of four levels. Simple description of levels is (from top to down) top, configuration, process element and implementation. Model contains standard descriptions of management processes, a framework of relationships among the standard processes, standard metrics to measure process performance, management practices that produce best-in-class performance and standard alignment to features and functionality. Some commercial supply chain management tools (for example SAP) use SCOR in their solutions.

6 Findings

6.1 Strategies for Identifying Critical Success Factors in Business Environment

There are different ways to manage and model a supply chain. The effect of business environment on the selection of modelling methods and tools is significant. Many companies have struggled with inappropriate modelling methods and given up the whole procedure. Therefore, it is important first to analyse the environment: define the most important characteristics, restrictions and problems of each environment and select between different modelling methods and tools after that.

When carrying out the analysis one has to consider the factors affecting supply chain performance. In inventory control policy these factors might be e.g. safety stock level, re-order point, inventory level of finished products, raw material and intermediate parts and stock location. When it comes to procurement and logistics, important factors are e.g. supplier lead-time, supply lot size, supplier capacity, and procurement horizon and procurement time. Important demand information consists of factors such as due date, priority, start and end data and demand pattern. Strategic information consists of order control policies and dispatch policies. [Chang et al. 2001]

In order to find critical success factors of a company we have to be familiar with the field of industry the company works in. After that, a strategic study about future business practices helps to give an insight into the company's logistics aims. Next, we should collect information from an operational level to be able to objectively connect strategic goals to tactical and operational business practices. For example, a SWOT-analysis is a suitable method for this.

6.2 Business Environments and Critical Factors of the Case Companies

Case companies of this study are not only from different fields of industries but also from different phases of a supply chain. Case company A is a project-oriented company working in the field of marine industry. The projects last for several years and the location of a site may be different in every project. Most projects are complex one-of-a-kind turn-key projects led by a consortium. There are multiple partners and suppliers all around the world. Therefore there is a wide field of technology, terms and standards to be combined. Partners and suppliers may change in almost every project, because due to many contractual terms, the main contractor is in many cases forced to use local suppliers and workforce. This may cause problems in resource management: terms, working habits and legislation are different. [Laurikkala et al., 2001]

There are few projects from which the history data for the planning basis for new projects and for forecasts could be collected. Still, both the completed and new projects should be grouped according to the most important features such as site location, consortium partners and project size and type. The emphasis should be in a thorough product, resource and business modelling, simulation and analysis of current and future business practices and on know-how transfer between similar projects.

There are not many suitable modelling methods or tools available for complex, multi-project environment. Simo-3, developed at Tampere University of Technology, is such a tool. It has been used for modelling and simulation of industrial projects in the field of power plants since 1999. The modelling is event-based, consisting of a hierarchical product model and resource, business and project models. Figure 3 illustrates the most critical factors in the business environment of a project company and the most critical business functions affecting the aforementioned factors.

Company B works in the field of food industry, producing meat, semi-finished products and bakery products. Therefore, there are specific requirements for temperature, hygiene, freshness and facilities though the production and the whole supply chain. The cycle is fast, delivery time being from 24 to 48 hours. The lifecycles of the products are quite long and there is plenty of

information available about past demand. This makes forecasting of future demand based on history data fairly straightforward. Though, the utilisation of demand forecast is the most challenging task. Were the production to be managed according to demand forecasts there should be a new and efficient production management system the output of which is versatile enough for modelling and simulation of the production. It should also be able to utilise the information from demand forecasts.

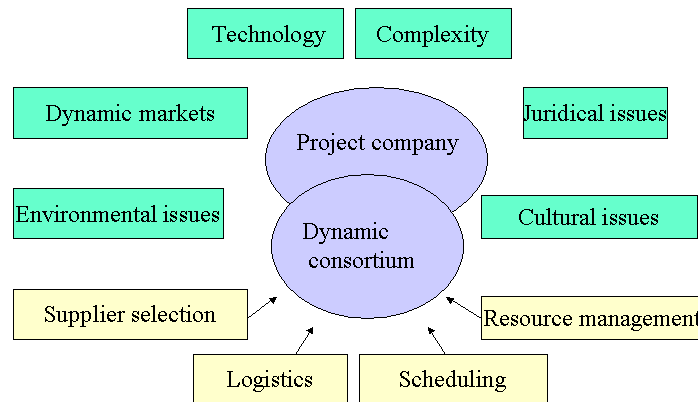


Figure 3: Business environment of a project company

As the products mainly exhibit long life cycles, we are able to use traditional time series methods in modelling the demand. We get fairly accurate forecasts for the products, as we have more than one year of data for many products. It is significant to have more than a year of data, because it makes possible to quantify the seasonal effects. For example for some products the demand in the summer can be six times the demand in the winter. Even the products with less than one year of data can be satisfactorily modelled, as the new products are often very similar to the old ones with little variation in demand behaviour.

The greatest challenge is to include the explanatory variables into the model. Prices, weather and sales promotions can cause some significant deviations from normal demand levels. Especially on daily level it is also important to be able to identify systematic changes from random changes. For example a day off in the middle of the week shifts most of the deterministic demand to the previous day. If this shift is not taken into consideration, our estimate of the variance increases.

One tool suitable for modelling supply chain and supporting flexible modelling and simulation is Simulink. It can be used for modelling and simulating the production of the food company and for using demand forecasts as input information. Figure 4 shows the most critical factors in the business environment of a food company and the most critical business functions affecting the aforementioned factors.

Case company C is a logistics company from the field of IT-wholesales. The delivery time is usually 24 hours, which requires efficient response time management, quick decisions and flexibility. The lifecycles of the products are short, ranging from a couple of months to a couple of years. This makes history-based forecasting demanding, because it is difficult to gather enough history data of a product before it goes out of the market. In order to be able to use the history data of other similar products the concentration should at first be on grouping the products according to carefully selected criteria.

The single product data is most likely contaminated by the fact that most of the products inside a product group are close supplements to each other. As we are interested in the demand of product and not its availability, we begin by modelling the demand behaviour of the product group.

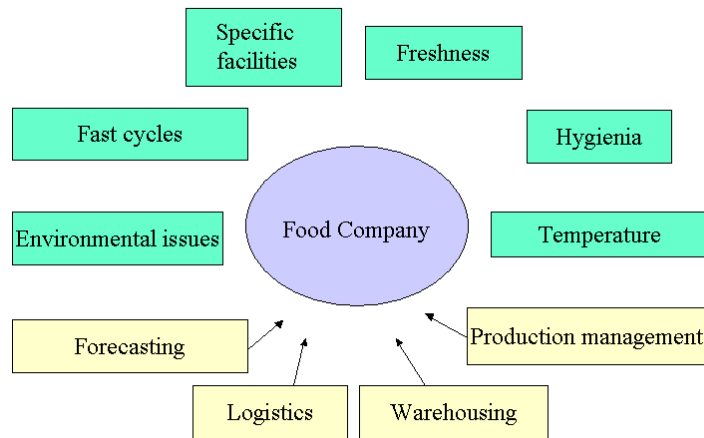


Figure 4: Business environment of a food company

The challenging task is to model how the demand is divided between different products. It can be possible that it is not useful to try to forecast each individual product, but rather some product clusters, which are very similar in their demand behaviour. Certainly, the forecast system needs to be a combination of expert information and statistical methods, where the expert is at first responsible in linking a new product to its most likely cluster. Modelling for this kind of environment can be done e.g. with Simulink and the algorithms for forecasting with Matlab. Figure 5 illustrates the most critical factors in the business environment of a wholesaler and the most critical business functions affecting the aforementioned characteristics.

Based on the results of this study, we provide Finnish companies with a modelling guidebook. The aim of the book is to support the companies in their modelling and to unify the modelling processes in the industry. It helps the companies to find appropriate modelling methods and tools for their business environment characteristics.

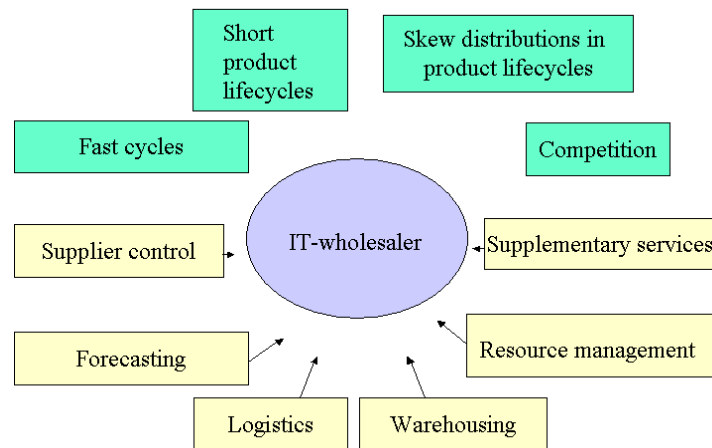


Figure 5: Business environment of IT-wholesaler

7 Conclusion

Modelling and control of supply chain based on demand forecasts is a challenging task. It requires thorough familiarisation with current business practices and future strategies of the companies involved. Similar modelling methods and tools should not be used to model different business environments but one should try to find the best possible method for each environment. The case companies of this study are from different fields of industries and therefore facing different problems and having different goals. They are also from different phases of a supply chain, the first being in a design and planning, the second in a production and the third in a wholesale phase.

The study shows that event-based models are suitable for environments with e.g. the following characteristics: complexity, dynamic markets, juridical and cultural issues, and wide field of technology. On the other hand, continuous models such as systems dynamics or transfer function models are appropriate for modelling fast cycle supply chains with specific requirements for e.g. temperature, hygienia, freshness, short lifecycles or skew distributions in product lifecycles.

One of the fundamental requirements for supply chain performance should be visibility of appropriate information in the right time and in the right format. Still, each company is only interested in its own phase of the supply chain, which makes the visibility requirement very difficult to fulfil. One should strive for unified modelling methods and tools for the whole supply chain in the same business area. A modelling guidebook for logistics is to provide the companies with support for their modelling efforts and to unify the modelling processes in the industry.

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